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# PERFORMANCE ANALYSIS AND SPEED CONTROL USING INDIRECT VECTOR CONTROLLED FOR INDUCTION MOTOR DRIVE

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**Abstract-** This paper presents the speed control scheme of an indirect vector-controlled induction motor (IM) drive. PWM controlling scheme is based on Voltage source inverter type space vector pulse width modulation (SVPWM) and the Conventional-PID controller or Fuzzy-PID controller is employed in closed-loop speed control. Decoupling of the stator current into torque and flux producing (d-q) current components model of an induction motor is involved in the indirect vector control. The torque component Iq current of an IM is developed by an intelligent-based Fuzzy PID controller. Based on settling time and dynamic response the performance of the Fuzzy Logic Controller is compared with that of the PID Controller to sudden load changes. It provides better control of motor torque with high dynamic performance. The simulated design is tested using various toolboxes in MATLAB. Simulation results of both controllers are presented for comparison.
**Keywords:** Indirect Vector Control (IVC), Space Vector Pulse Width Modulation (SVPWM), PID Controller, Fuzzy Logic Controller (FLC).

## 1. INTRODUCTION

In the recent era, the field-oriented control of induction motor drive is normally used in high-performance drive system because of its benefits [1]. Most of the industries need adjustable speed drives. Even though many investigations have been carried out for decades for the efficient control of the speed of induction motors [2], since last two decades the progress of semiconductor technology has laid suitable spark that the static frequency converters can now be introduced at the acceptable cost.

The speed control of separately excited dc drives is simple because independent control of flux and torque can be brought about. Although, induction motors involve a coordinated control of stator current magnitude and the phase, making it a complex control. The rotor flux linkages can be resolved along with any frame of reference. For achieving this, the position of the flux linkages at every instant is required. Then the control of the induction motor is very similar to that of a separately excited dc motor [3] [4]. Therefore this control involves field coordinates; it is also called field-oriented control [5]. The name vector control evolved requirement of the phase angle of the flux, a linkage in the control process gives the name vector control.

An advanced, computationally intensive and possibly the best among all the PWM techniques for variable frequency drive application is The Space Vector Pulse Width Modulation (SVPWM) method [6]. It shows the feature of good dc-bus voltage utilization and low THD compared to other PWM methods. SVPWM is the best fit for digital implementation and can increase the obtainable maximum output voltage with a maximum line voltage approaching 70.7% of the DC link voltage in the linear modulation range [7-9].

The conventional speed control methods have the following difficulties to achieve the desired control, it depends on the accuracy of the mathematical model of the systems, and the expected performance is not met due to the load disturbance, classical linear control shows good performance only at one operating speed. Fuzzy logic is a technique to represent human-like thinking into a control system [9]. A fuzzy controller can be designed to emulate human deductive thinking, that is, the process people use to assume conclusions from what they know. The control of processes is applied through fuzzy linguistic descriptions [10-12].

In this paper, the speed control of SVPWM-based Indirect Vector Controlled Induction Motor using fuzzy PID control and the proposed design is tested by MAT LAB/Simulink. The second section of this paper covers Indirect Vector Control. Space vector Pulse Width Modulation is covered in the third section of the paper. The fourth section deals with the Design of Fuzzy PID control. The results and discussions are covered in the fifth section. The conclusion OF this paper is in the last section.

## 2. INDIRECT VECTOR CONTROL

Fig. 2.1 depicts an indirect vector control method. As compared to the direct vector control method, it uses the indirect estimation of the slip speed and a feed-forward method of control.

The speed error, with the help of a Conventional PID and/or Fuzzy PID intelligent controller, is converted into a torque-controlling current component iqs*, of the stator current. To regulate the torque and the slip speed, the current component iqs* is used.


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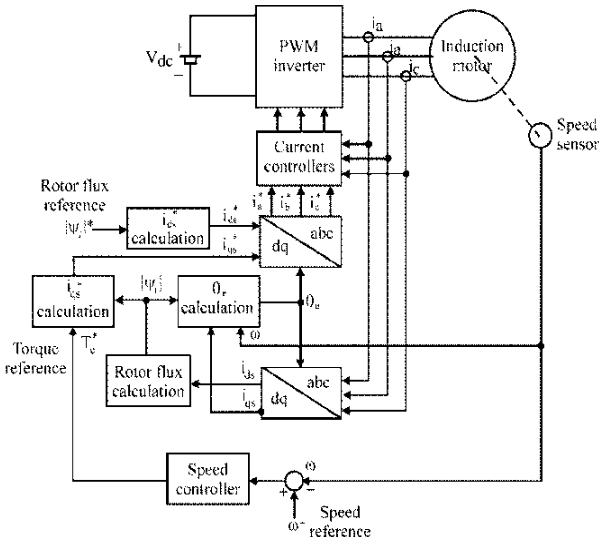


**Fig. 2.1 Indirect Estimation of the Speed**

## 3. SPACE VECTOR PULSE WIDTH MODULATION

$V_1$, $V_2$, $V_3$, $V_4$, $V_5$, $V_6$ are six active vectors and $V_0$ and $V_7$ are labeled as two zero vectors. If these 8 voltage vectors are converted to 2 axes, it can be plotted as shown in Fig. 3.1 the tips of the 6 non-zero vectors, when cornered form a regular hexagon with the two zero vectors lying at the origin.

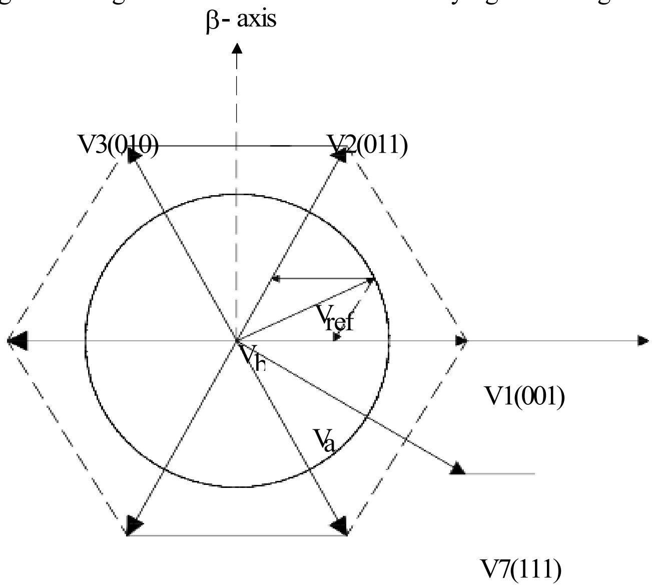


**Fig. 3.1 Space Voltage Vectors of a Three-Phase VSI**

**Table -3.1 Summary of Inverter Switching States**

| Name | A | B | C | $V_{An}$ | $V_{Bn}$ | $V_{Cn}$ |
|---|---|---|---|---|---|---|
| V0 | 0 | 0 | 0 | 0 | 0 | 0 |
| V1 | 1 | 0 | 0 | 2VDC/3 | -VDC/3 | -VDC/3 |
| V2 | 1 | 1 | 0 | VDC/3 | VDC/3 | -2VDC/3 |
| V3 | 0 | 1 | 0 | -VDC/3 | 2VDC/3 | -VDC/3 |
| V4 | 0 | 1 | 1 | -2VDC/3 | VDC/3 | VDC/3 |
| V5 | 0 | 0 | 1 | -VDC/3 | -VDC/3 | 2VDC/3 |
| V6 | 1 | 0 | 1 | VDC/3 | -2VDC/3 | VDC/3 |
| V7 | 1 | 1 | 1 | 0 | 0 | 0 |


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## 4. DESIGN OF CONTROLLER

### 4.1 Conventional PID Controller

The conventional PID controller is one of the most common (almost 90%) approaches for speed control in industrial electrical drives in general, because of its simplicity, and the clear relationship existing between its parameters and the system response specifications. A very common method to determine the Kp, Ki and Kd constants of this controller is the method of Ziegler-Nichols. The conventional PID controller block model is given in Fig. 4.1.

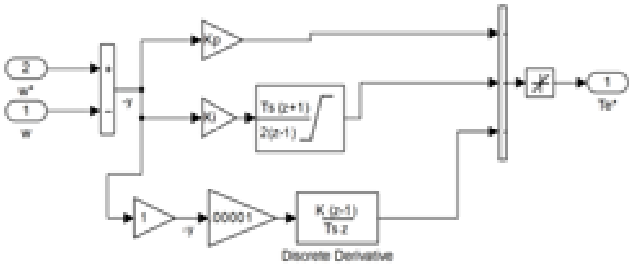


**Fig. 4.1 Conventional PID Controller**

The conventional PID controller for constant gain may perform well under some operating conditions but not at all, because the processes are generally complex, time-variant, with nonlinearity and model uncertainties.

### 4.2 Fuzzy PID Controller

The first step is to find the degree of each data values in every membership region of its corresponding fuzzy domain to determine a fuzzy rule from each input-output data pair. The value of the variable is assigned to the region with the maximum degree. After generating new rules from the input-output data pairs, a rule degree or truth is assigned to that rule, where these rule degrees are defined as the degree of confidence that the rule does, in fact, correlate to the function relating voltage and current to angle. For this developed method, a degree is assigned which is the product of the membership functions of each variable in its respective region.

Each training data set produces a corresponding fuzzy rule, is stored in the fuzzy rule base. Thus rules are generated, as each input-output data pair is processed. A fuzzy rule or knowledge base is in the form of two-dimensional tables, which can be looked up by the fuzzy reasoning mechanism.

Speed error is calculated with a comparison between reference speed and speed signal feedback. Speed error and speed error changing are fuzzy controller inputs.

### 4.3 Membership Functions

The Fuzzy Logic Controller initially converts the crisp error and change in error variables into fuzzy variables and then are mapped into linguistic labels. Membership functions are associated with each label as shown in Fig. 4.2 and 4.3 which consists of two inputs and one output.

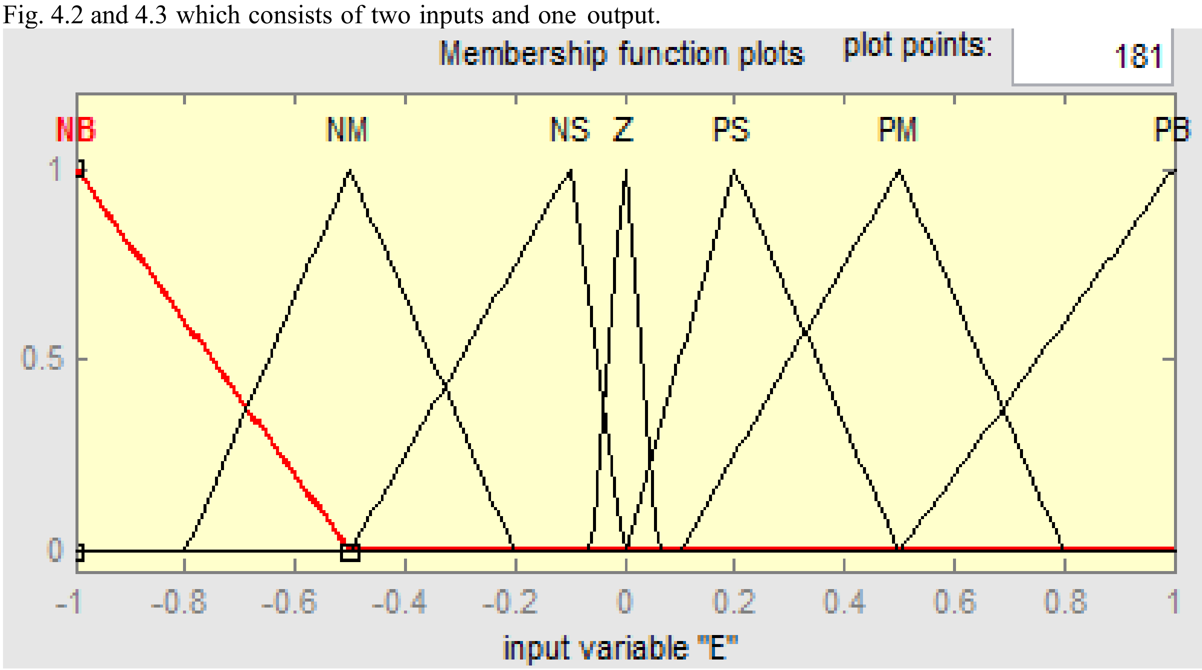


**Fig. 4.2 Speed Error (e)**



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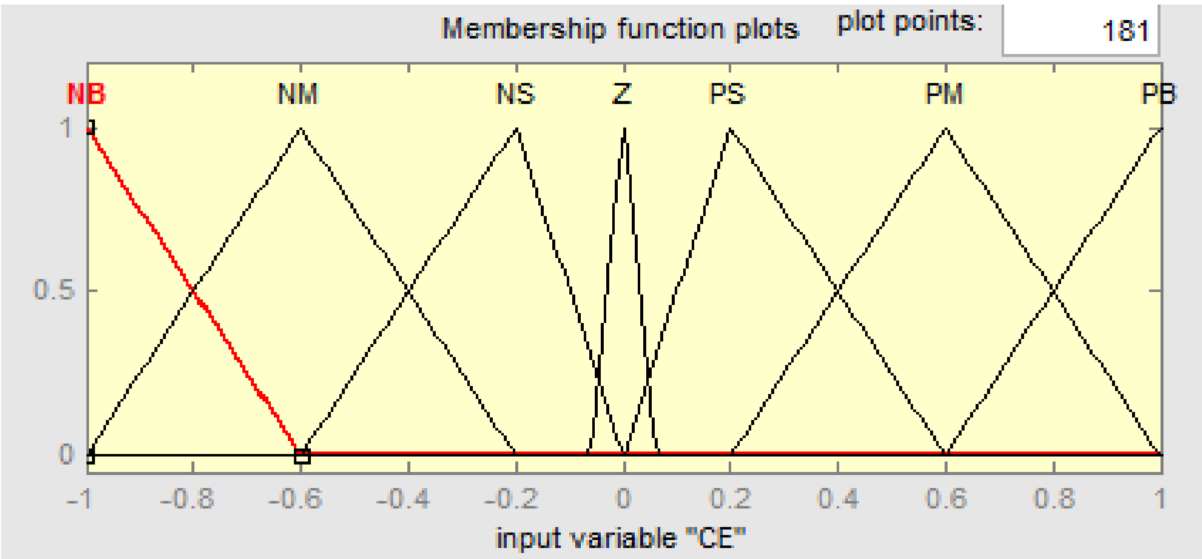
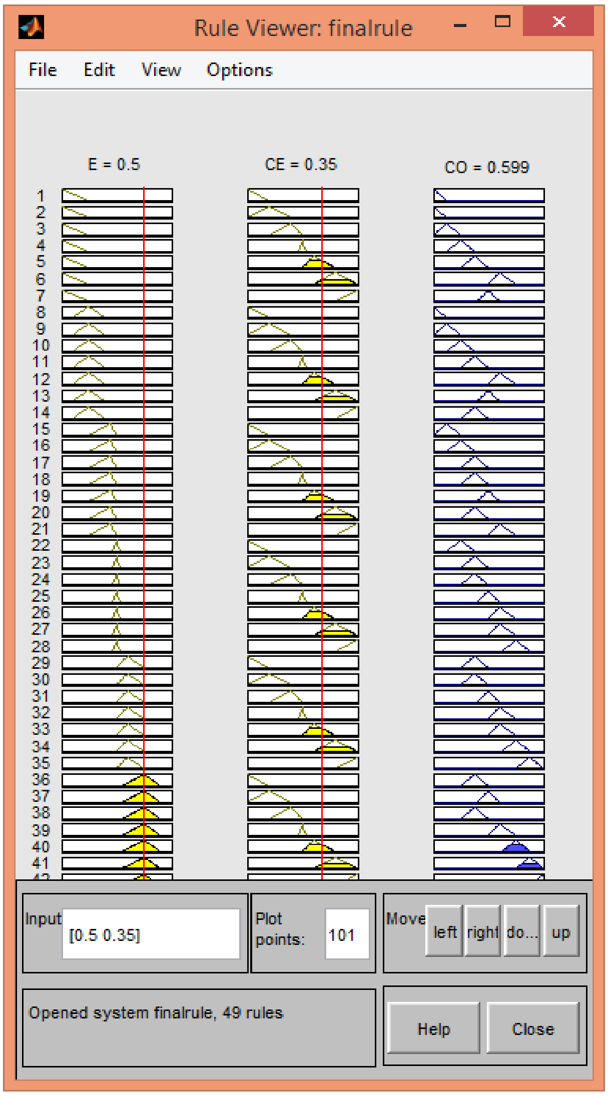



**Fig. 4.3 Change in Speed Error (ce)**




**Output (u)**

**Fig. 4.4 Membership Function Plots**

The linguistic labels are divided into seven groups. They are nl-negative large, nm-Negative medium, ns-negative small, z-zero, ps-positive small, pm-positive medium, and pl-positive large. Each of the inputs and the output contains membership functions with all these seven linguistics.



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### 4.4 Knowledge Rule Base

The mapping of the fuzzy inputs into the required output is derived with the help of a rule base as given in Table 4.1.

**Table-4.1 Rule Base of Fuzzy Speed Control**

| e\ce | NB | NM | NS | Z | PS | PM | PB |
|---|---|---|---|---|---|---|---|
| NB | NVB | NVB | NB | NM | NS | PS | Z |
| NM | NVB | NB | NM | NS | PS | Z | NS |
| NS | NB | NM | NS | NS | Z | NS | PS |
| Z | NM | NS | NS | Z | PS | PS | PM |
| PS | NS | NS | Z | PS | PS | PM | PB |
| PM | NS | Z | NS | PS | PM | PB | PVB |
| PB | Z | PS | PS | PM | PB | PVB | PVB |

## 5. RESULTS AND DISCUSSION

For the evaluation of implemented drive, different responses of a drive are presented. Starting response of 120 rps reference speed with conventional PID and fuzzy PID Response has drawn for 0.25 seconds that motor speed is according to rps. It is concluded that the FLC-based system is superior to the conventional PID-based drive system in all aspects: rise time, settling time and overshoot and % of error.

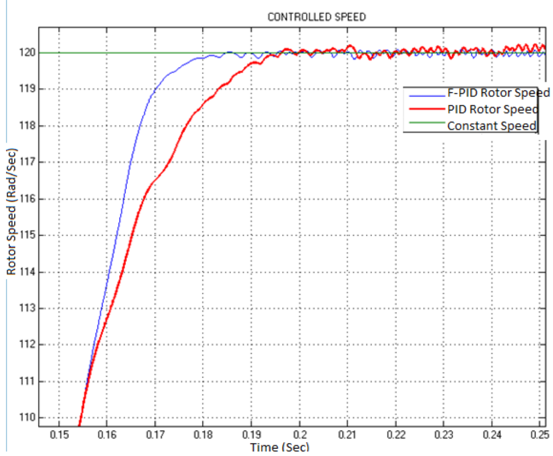


**Fig. 5.1 Starting Response**

The torque change response, shown in Fig. 5.2 reflects the response in the load condition is quick for the Fuzzy PID controller compared with the Conventional PID controller.

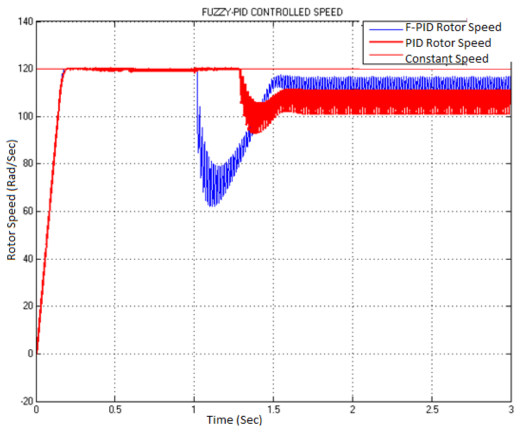


**Fig. 5.2 Torque Change from 0 Nm to 7 Nm**

## CONCLUSION

In this paper, the concept of fuzzy logic has been presented and the SVM-based indirect vector-controlled induction motor drive is simulated using both PID and Fuzzy PID controller in hybrid model. The results of



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both controllers under the dynamics conditions are compared and analyzed. The simulation result supports the FLC, settles quickly and has better performance than when PID controller.

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